Practice patterns of carotid endarterectomy as performed by different surgical specialties at a single institution and the effect on perioperative stroke and cost of preoperative imaging

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Background: **Carotid endarterectomy (CEA) is currently performed by various surgical specialties with varying outcomes. This study analyzes different surgical practice patterns and their effect on perioperative stroke and cost.**

Methods: **This is a retrospective analysis of prospectively collected data of 1000 consecutive CEAs performed at our institution by three different specialties: general surgeons (GS), cardiothoracic surgeons (CTS), and vascular surgeons (VS).**

Results: **VS did 474 CEAs, CTS did 404, and GS did 122. VS tended to operate more often on symptomatic patients than CTS and GS: 40% vs 23% and 31%, respectively ($P < .0001$). Preoperative workups were significantly different between specialties: duplex ultrasound (DUS) only in 66%, 30%, and 18%; DUS and computed tomography angiography in 27%, 35%, and 29%; and DUS and magnetic resonance angiography in 6%, 35%, and 52% for VS, CTS, and GS, respectively ($P < .001$). The mean preoperative carotid stenosis was not significantly different between the specialties. The mean heparin dosage was 5168, 7522, and 5331 units ($P = .0001$) and protamine was used in 0.2%, 19%, and 8% ($P < .0001$) for VS, CTS, and GS, respectively. VS more often used postoperative drains; however, no association was found between heparin dosage, protamine, and drain use and postoperative bleeding. Patching was used in 99%, 93%, and 76% ($P < .0001$) for VS, CTS, and GS, respectively. Bovine pericardial patches were used more often by CTS and ACUSEAL (Gore-Tex; W. L. Gore and Associates, Flagstaff, Ariz) patches were used more often by GS ($P < .0001$). The perioperative stroke/death rates were 1.3% for VS and 3.1% for CTS and GS combined ($P = .055$); and were 0.7% for VS and 3% for CTS and GS combined for asymptomatic patients ($P < .034$). Perioperative stroke rates for patients who had preoperative DUS only were 0.9% vs 3.3% for patients who had extra imaging (computed tomography angiography/magnetic resonance angiography; $P = .009$); and were 0.9% vs 3% for asymptomatic patients ($P = .05$). When applying hospital billing charges for preoperative imaging workups (cost of DUS only vs DUS and other imaging), the VS practice pattern would have saved \$1180 per CEA over CTS and GS practice patterns; a total savings of \$1,180,000 in this series.**

Conclusions: **CEA practice patterns differ between specialties. Although the cost was higher for non-VS practices, the perioperative stroke/death rate was somewhat higher. Therefore, educating physicians who perform CEAs on cost-saving measures may be appropriate. (J Vasc Surg 2014;60:1232-7.)**

Carotid endarterectomy (CEA) is currently one of the most commonly performed vascular procedures in the United States. Different surgical specialists perform this procedure, including vascular surgeons (VS), cardiothoracic surgeons (CTS), general surgeons (GS), neurosurgeons, and otorhinolaryngologists.[1] Since its introduction in the early 1950s, several technical aspects have been debated, including CEA with primary closure, CEA with patch closure, and eversion CEA. Other aspects of the procedure can vary greatly according to the operator, such as the type of anesthesia, the use of intraoperative heparin, the dose of heparin, the use of intraoperative shunting, the type of patch used for closure, the use of drains, and the use of protamine at the completion of the procedure.

Several preoperative imaging modalities can be used before CEA, including carotid duplex ultrasound (CDUS) imaging, computed tomography angiography (CTA), and magnetic resonance angiography (MRA). At many centers, CDUS imaging is reliable and used as the sole preoperative imaging, particularly when these US assessments are done in an accredited vascular laboratory.

We previously reported on the effect of surgeon specialty and volume on the perioperative outcome of CEA.[2] In the present study, we are reporting the practice patterns

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Table I. A, Type of preoperative imaging in all patients by specialty

Type of carotid imaging	*Specialty* *VS,* *No. (%)*	*CTS,* *No. (%)*	*GS,* *No. (%)*	*Total*	P
CDUS only	311 (66)	120 (30)	22 (18)	453	
CDUS and CTA	130 (27)	141 (35)	35 (29)	306	
CDUS and MRA	28 (6)	140 (35)	63 (52)	231	
CDUS, CTA, and MRA	5 (1)	3 (0.7)	2 (2)	10	
CDUS and other imaging	163 (34)	284 (70)	100 (82)	547	<.0001
Total	474	404	122	1000	

CDUS, Carotid duplex ultrasound; *CTA,* computed tomography angiography; *CTS,* cardiothoracic surgeons; *GS,* general surgeons; *MRA,* magnetic resonance angiography; *VS,* vascular surgeons.

of CEA as performed by different surgical specialties and their effect on perioperative outcome (stroke) and cost.

METHODS

The Charleston Area Medical Center/West Virginia University Institutional Review Board approved this study and all patients gave informed consent.

Patient population. This is a retrospective analysis of prospectively collected data of 1000 consecutive CEAs performed at our institution by three different surgical specialties as defined by the American Board of Medical Specialties: GS, CTS, and VS (with an additional approved vascular fellowship after general surgery training). Patient clinical characteristics and demographics were recorded. Physicians' notes, nurses' notes, and preoperative imaging and operative reports were reviewed for each patient. Preoperative imaging included CDUS or CTA and MRA, or both. The 30-day perioperative data were obtained from hospital, office, primary/referring physician records, and telephone interviews with physicians or patients, if necessary. The study excluded patients who had sequential bilateral CEA during the same hospitalization, combined CEA and coronary artery bypass grafting, CEA for acute stroke (defined as ≥3 Rankin scale or within 1 week of stroke, or both), or redo CEA.

Carotid stenosis was defined as asymptomatic or symptomatic according to North American Symptomatic Carotid Endarterectomy Trial (NASCET) criteria.[3] The degree of carotid stenosis was also determined from the vascular laboratory reports, which were previously validated using the NASCET measurements.[3]

All CEAs were done under general anesthesia with systemic heparin and routine shunting. The following practice pattern variables between VS, GS, and CTS were recorded and analyzed: the use of preoperative CDUS only before CEA, the use of preoperative CDUS with CTA or MRA, and the use of preoperative CDUS and both CTA and MRA. The mean preoperative carotid stenosis for both symptomatic and asymptomatic indications, the mean heparin dosage, the use of protamine, the use and type of patching, the use of postoperative drains, and indications for CEA according to specialty were also analyzed. All 30-day perioperative strokes and deaths were also analyzed. Postoperative CT or magnetic resonance imaging scans, or both, were performed on patients who manifested neurologic events (stroke/transient ischemic attacks). These patients were evaluated by the surgeons or neurologists, or both.

Cost analysis of preoperative carotid imaging and specialty. We applied hospital billing charges for preoperative imaging workups before CEA, according to Current Procedural Terminology (CPT) codes (American Medical Association, Chicago, Ill) to analyze the preoperative cost per each CEA according to the practice pattern for each specialty. The cost for CDUS (CPT code 93880) was $750 (for both technical and professional components), the cost for carotid CTA (CPT code 70498) was $1842, and the cost for carotid MRA (CPT code 70548) was $3288. The cost of preoperative imaging for all CEAs done by each specialty group was divided by the number of CEAs done by each group to determine the average cost of imaging per one CEA.

Statistical methods. The data analysis was performed using SAS 9.2 software (SAS Institute, Cary, NC). Comparisons of categoric variables were performed using a contingency table analysis with a χ^2 test or Fisher exact test to determine statistically significant differences. An α level of ≤.05 was used to determine statistical significance.

RESULTS

This study included 1000 CEAs: 474 were done by five VS, 404 by 13 CTS, and 122 by seven GS. Patient demographic and clinical characteristics were similar for the three groups, except for history of coronary artery disease (defined by angina, past myocardial infarction, percutaneous transluminal coronary angioplasty, or coronary artery bypass), which was higher for patients of the CTS ($P < .0001$). VS tended to operate more often on symptomatic patients than CTS and GS: 40% vs 23% and 31%, respectively ($P < .0001$). Preoperative carotid imaging workup were significantly different between specialties: CDUS only in 66% for VS, 30% for CTS, and 18% for GS; DUS and CTA in 27% for VS, 35% for CTS, and 29% for GS; DUS and MRA in 6% for VS, 35% for CTS, and 52% for GS, ($P < .001$; Table I, *A*).

Table I. B, Type of preoperative imaging in asymptomatic patients by specialty

Type of carotid imaging	Specialty			Total	P
	VS, No. (%)	CTS, No. (%)	GS, No. (%)		
CDUS only	206 (72)	93 (30)	19 (23)	318	
CDUS and CTA/MRA	81 (28)	220 (70)	65 (77)	366	<.0001
Total	287	313	84	684	

CDUS, Carotid duplex ultrasound; *CTA,* computed tomography angiography; *CTS,* cardiothoracic surgeons; *GS,* general surgeons; *MRA,* magnetic resonance angiography; *VS,* vascular surgeons.

Table I, *B* summarizes the preoperative workup in asymptomatic patients only. Similar observations were noted where other imaging (CTA/MRA), in addition to CDUS, were used more often by CTS (70%) and GS (77%) than by VS (28%). The mean preoperative carotid stenosis was not significantly different between the specialties (76% for VS, 75% for CTS, and 77% for GS, a mean of 50%-99%).

The mean heparin dosage was 5168 units for VS (range, 3000-10,000 units), 7522 units for CTS (range, 4000-25,000 units), and 5331 units for GS (range, 4000-10,000 units; $P = .0001$), whereas protamine was used in 0.2%, 19%, and 8% of patients ($P < .0001$) for VS, CTS, and GS, respectively. Postoperative drains were used less often by VS (73%) vs CTS (99.5%) and GS (95%; $P < .0001$; Table II). No association was found between heparin dosages, protamine use, and drain use and postoperative bleeding (Table III). The overall incidence of perioperative bleeding (hematoma) was 4.2% for VS, 2.9% for CTS, and 2.5% for GS ($P = .4835$). Patching (CEA with patch closure) was used in 99% for VS, 93% for CTS, and 76% for GS ($P < .0001$). Bovine pericardial patches were used more often by CTS (81%) vs VS (62%) and GS (11%), whereas ACUSEAL (Gore-Tex; W. L. Gore and Associates, Flagstaff, Ariz) patches were used more often by GS (89%) vs VS (37%) and CTS (3%; $P < .0001$).

The 30-day perioperative stroke/death rates were 1.3% for VS, 2.7% for CTS, and 4.1% for GS ($P = .1065$) and 3.1% for CTS and GS combined ($P = .05$). These rates were 0.7% for VS and 3% for CTS and GS combined (2.9% for CTS and 3.6% for GS) for asymptomatic patients ($P < .034$), and 2.1% for VS, 2.2% for CTS, and 5.3% for GS for symptomatic patients ($P = .4937$). Overall, 22 perioperative strokes occurred in the entire series (2.2% stroke rate), 18 of 964 (1.9%) for patching vs four of 36 (11.1%) for primary closure ($P = .0065$). The 30-day perioperative stroke rate was 0.9% for all patients who had preoperative DUS only vs 3.3% for patients who had extra preoperative imaging (CTA/MRA; $P = .009$); and was 0.9% for asymptomatic patients who had preoperative DUS only vs 3% ($P = .05$) for patients who had extra preoperative imaging.

Table II. The use of postoperative drains by specialty

Drain	Specialty			Total	P
	VS, No. (%)	CTS, No. (%)	GS, No. (%)		
No	130 (27)	2 (0.5)	6 (5)	138	<.0001
Yes	344 (73)	402 (99.5)	116 (95)	862	
Total	474	404	122	1000	

CTS, Cardiothoracic surgeons; *GS,* general surgeons; *VS,* vascular surgeons.

Preoperative imaging workup for CEA and cost analysis. When applying hospital billing charges for preoperative imaging work-ups for CEA (cost of DUS only vs DUS and other imaging), the VS practice pattern would have saved $1180.51 per CEA over CTS and GS practice patterns; a total savings of $1,180,510 in this series (Table IV). The savings was $1307.80 for each asymptomatic CEA.

DISCUSSION

CEA is one of the most commonly performed operations by VS today. Other specialists that perform CEAs include CTS, GS, neurosurgeons, and otorhinolaryngologists.[1] The three basic approaches to performing a CEA are a standard endarterectomy with patch closure, eversion endarterectomy, and endarterectomy with primary closure. Although most surgeons use one of these three techniques, other aspects of the procedure can vary greatly, such as the use and dosage of heparin intraoperatively, antiplatelet therapy preoperatively and postoperatively, the use of intraoperative shunting, the type of patch used for a patch closure, the use of drains, and the use of protamine at the completion of the procedure. In addition, a variety of imaging modalities are afforded each participating surgeon in the preoperative workup and in postoperative surveillance. These include CDUS imaging, CTA, MRA, and standard angiography.

This study reviewed 1000 consecutive CEAs in a single institution performed by VS, CTS, and GS and analyzed various practice patterns in an attempt to determine their effect on perioperative outcome and cost. We previously reported the effect of a surgeon's specialty and volume on perioperative outcome of a CEA, and that will not be discussed here.[2]

The current study analyzed heparin dosage, protamine use, and drain use to determine their effect on postoperative bleeding and, hence, the potential relation that this could have on adverse perioperative outcomes. Although heparin dosage, protamine use, and drain use varied significantly among the three specialty groups, with CTS using more heparin and protamine and VS using more drains, no association was found between these variables and postoperative bleeding. Furthermore, patient mean preoperative carotid stenosis was not significantly different among these groups.

Patching was used in 99% of cases by VS vs 93% for CTS and 76% for GS ($P < .0001$). We previously reported

Table III. Drain and exploration for bleeding

Variable	*VS, No. (%)*	*CTS, No. (%)*	*GS, No. (%)*	*Total*	P
No drain used					
Exploration for bleeding					
No	128 (98.5)	2 (100)	6 (100)	136	1
Yes	2 (1.5)	0	0	2	
Total	130	2	6	138	
Drain used					
Exploration for bleeding					
No	334 (97)	395 (98)	114 (98)	843	.519
Yes	10 (3)	7 (2)	2 (2)	19	
Total	344	402	116	862	

CTS, Cardiothoracic surgeons; *GS,* general surgeons; *VS,* vascular surgeons.

Table IV. Cost analysis of imaging before carotid endarterectomy (*CEA*) by specialty

Variable	*Specialty*		
	VS	*CTS/GS*	*Total*
All patients			
CDUS only, No. (%)	311 (66)	142 (27)	453
CDUS and CTA, No. (%)	130 (27)	176 (33)	306
CDUS and MRA, No. (%)	28 (6)	203 (39)	231
CDUS, CTA, and MRA, No. (%)	5 (1)	5 (1)	10
Total	474	526	1000
Average cost of imaging per 1 CEA, $	1503.53	2684.04	2124.48
Perioperative stroke, %	1.3	3.1	2.2
Asymptomatic patients			
CDUS only, No. (%)	206 (71.8)	112 (28.2)	318
CDUS and CTA, No. (%)	69 (24)	133 (33.5)	202
CDUS and MRA, No. (%)	11 (3.8)	148 (37.3)	159
DUS, CTA, and MRA, No. (%)	1 (0.4)	4 (1)	5
Total	287	397	684
Average cost of imaging per 1 CEA, $	1336.75	2644.53	2095.80
Perioperative stroke, %	0.7	3	2.05

CDUS, Carotid duplex ultrasound; *CTA,* computed tomography angiography; *CTS,* cardiothoracic surgeons; *GS,* general surgeons; *MRA,* magnetic resonance angiography; *VS,* vascular surgeons.

that patching was a significant predictor for lowering the perioperative stroke rates in multivariate analysis model.[2] The perioperative stroke rate was 1.9% (18 of 964) for patching vs 11.1% (four of 36) for primary closure in the present series (P = .0065). In addition, although the type of patch used varied among the three groups, with more bovine pericardium by CTS and ACUSEAL by GS, this had no statistically significant effect on perioperative stroke and death outcomes.

Our study did show that VS used CDUS imaging as the sole preoperative modality more often than the other specialty groups, with VS using CDUS only in 66% of patients vs 30% for CTS and 18% for GS. VS also used less additional preoperative imaging studies, with VS using CDUS and CTA in 27%, whereas CTS used both in 35% and GS used both in 29%. VS rarely relied on additional MRA studies, adding this study to the CDUS in only 6% of patients. CTS and GS used MRA much more often as an adjunct to CDUS, at 35% and 52%, respectively.

This translated into significant cost benefits for using CDUS alone. The CDUS cost was $750, whereas a carotid CTA was $1842 and an MRA was $3288. When calculating the hospital billing charges for CDUS only against CDUS and other imaging, the VS practice pattern saved approximately $1181 per CEA over the CTS and GS practice patterns, for a total savings of ~$1,181,000 in this series.

Our data also demonstrate reduced perioperative stroke and death rates for patients with preoperative CDUS only. The 30-day perioperative stroke rate was only 0.9% for all patients with preoperative CDUS vs 3.3% (P = .009) for those patients who had additional preoperative imaging. This result was again seen with asymptomatic patients, with a 0.9% perioperative stroke rate for patients with preoperative CDUS only vs 3% for those who had additional preoperative imaging along with CDUS.

At first glance, it appears by our data that obtaining only a preoperative CDUS provides a significant advantage over obtaining additional imaging in reducing the risk of perioperative stroke as well as in reducing perioperative cost. However, 66% of VS used CDUS only for their preoperative workup, whereas 30% of CTS and 18% of GS used CDUS as the sole preoperative imaging modality. When taking into account that the 30-day perioperative stroke and death rates were 1.3% for VS and 3.1% for CTS and GS combined, and 0.7% for VS and 3% for CTS and GS combined for asymptomatic patients, the benefit of obtaining only a CDUS may simply be a reflection of *who* is ordering the imaging and not that CDUS was ordered alone. In other words, the surgeons in our study with the lowest perioperative stroke and death rates were those who relied on CDUS only for a significant amount of their interventions. Our results on additional imaging should be interpreted with caution, especially regarding asymptomatic patients. The VS in our series tended to operate more often on symptomatic patients than CTS and GS, and based on current treatment recommendations according to the updated Society for Vascular Surgery (SVS) guidelines,[4] a surgeon may not find it critical to obtain any further confirmatory imaging beyond CDUS. These findings do demonstrate, however, that one can obtain excellent perioperative stroke and death rates in performing CEA using only a CDUS as the sole preoperative imaging modality and that further preoperative imaging is not always necessary in planning carotid surgery, particularly for asymptomatic patients. This not only confers a degree of safety to the patient in reduced radiation and contrast exposure but also in cost reduction to the patient and the medical system. Certainly, there may be unusual circumstances in which obtaining additional imaging would be beneficial, such as anatomical constraints to CDUS imaging or limited CDUS visualization due to artifact, the need for exact anatomical measurements if a complex carotid reconstruction is a possibility, or if the CDUS findings do not correlate with the neurologic events. However, our findings show that preoperative CDUS is a reliable and economical imaging modality to plan for carotid surgery.

Many studies have emphasized the use of CDUS as the sole imaging modality for planning carotid surgery.[5-11] However, some challenge this conclusion and believe additional imaging is necessary.[12] The SVS recently updated its practice guidelines and directly discussed the issue of carotid imaging in preparing for carotid surgery.[4] Specifically, the guidelines state that a CDUS from an accredited vascular laboratory is sufficient to make a decision regarding carotid surgery for symptomatic patients with a stenosis of 50% to 99% by US evaluation and for asymptomatic patients with a stenosis of 70% to 99%. Furthermore, the guidelines point out that when CDUS is nondiagnostic or suggests a stenosis in the range of 50% to 69% in asymptomatic patients, additional imaging with CTA, MRA, or angiography is warranted. Thus, the SVS practice guidelines clearly endorse CDUS as the sole imaging modality in planning for carotid surgery and recommend further imaging only in select circumstances.

This current study has the usual limitations of being a retrospective analysis, and reporting bias likely contributes to some degree of error because no CTS or GS were involved in data collection. However, individual surgeons were not allowed to collect their own data, and a medical biostatistician and senior general surgical residents verified all perioperative outcomes.

This study is also limited because it did not consider the cost of other CDUS, which may have been done in nonaccredited vascular laboratories before the patient's admission. It should be noted that the VS group obtained all of its CDUS in the accredited vascular laboratory at our institution. The VS group in our center also had somewhat similar process of care in performing CEA, using patch closure uniformly, in contrast to the CTS and GS, who had a different background of training and performing CEA.

CONCLUSIONS

CEA practice patterns vary between specialties. We believe that our study demonstrates the effectiveness of CDUS in the evaluation and preparation of patients for carotid interventions and that, if used properly within the SVS guidelines and with an understanding of its benefits and limitations, CDUS can be an integral part of a cost-effective practice pattern for carotid surgery. Other operative variables, such as heparin dosage, protamine use, drain use, type of patch used, and degree of carotid stenosis, failed to demonstrate any significant effect on adverse outcomes or cost benefit for CEA. Therefore, educating physicians who perform CEAs on cost-saving measures may be appropriate.

AUTHOR CONTRIBUTIONS

Conception and design: AA, MS, SH, BC, ZA, LD, PS, AM
Analysis and interpretation: AA, MS, LD
Data collection: AA, MS, SH, BC, ZA, PS, AM
Writing the article: AA, SH
Critical revision of the article: AA, SD, SH
Final approval of the article: AA, MS, SH, BC, ZA, LD, PS, AM
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